THE CHARACTERIZATION OF MECHANICAL BEHAVIOUR ON KENAF FIBRE / POLYPROPYLENE COMPOSITES

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Special dedication to all my beloved peoples

Rosmah Binti Ahmad & Mat Husin Bin Sulaiman

Nurul Aishah Binti Sajar, Siti Zulaikha Binti Mat Husin,

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ABSTRACT

Global demand for wood plastic composite (WPC) has increased due to the increase of population and latest applications primarily in Malaysia industry today such as decking, chair and ceiling. However, the current WPC is worth investigating since such materials can be explored by enhancing their strength and quality through the treatment method. The objective of this study is to identify the effect of alkaline treatment on kenaf fibre in WPC system, to investigate the highest strength of kenaf fibre loading on mechanical properties in WPC, and to evaluate the morphology characteristics from fracture specimens related to the mechanical testing via scanning electron microscopy (SEM). Specimen was fabricated via injection moulding and hydraulic hot press using kenaf fibre (KF) as filler and polypropylene (PP) as the matrix. A tensile test was carried out to determine the tensile stress of the material. The result revealed treated specimen possesses high tensile stress at 5 wt.% sodium hydroxide (NaOH) compared to 10 wt.% and 20 wt.%. The optimum tensile stress was at 40 wt.% KF (5 wt.% NaOH, 5 wt.% MAPP) with the value 21.38 MPa. Flexural test was carried out on untreated and treated KF which is pure PP, 10 wt.% KF, and 20 wt.% KF by weight to PP. The result of flexural stress showed treated specimen lead better flexural at 20 wt.% PP/KF (5 wt.% NaOH) with 30.25 MPa. Meanwhile 40 wt.% KF (5 wt.% MAPP) give high fatigue life cycles at all stress level 90 %, 80 %, 70 %, 60 % and 50 % as the specimen structure less damage was induced during fatigue test. SEM is used to observe the morphological characteristics of PP/KF. The good interfacial bonding between KF and PP is 5 wt.% NaOH due of less impurities and lignin content. Overall 5 wt. % NaOH with 40 wt.% PP/KF (5 wt.% MAPP) showed the best result and it is worth to replace the current kenaf fibre polymer composites product.

ABSTRAK

Permintaan global untuk kayu plastik campuran (WPC) telah meningkat berikutan peningkatan populasi dan aplikasi terkini terutamanya dalam industri Malaysia hari ini seperti lantai, kerusi dan siling. Walau bagaimanapun, WPC semasa adalah bernilai dikaji kerana bahan tersebut dapat diteroka dengan meningkatkan kekuatan dan kualiti melalui kaedah rawatan. Objektif kajian ini adalah untuk mengenalpasti kesan rawatan alkali pada gentian kenaf dalam sistem WPC, untuk mengkaji kekuatan tertinggi pemuatan gentian kenaf pada sifat mekanikal di WPC, dan untuk menilai ciri-ciri morfologi daripada spesimen patah yang berkaitan dengan ujian mekanikal melalui pengimbasan mikroskop elektron (SEM). Spesimen dibuat melalui pengacuan suntikan dan hidraulik pemanas tekanan menggunakan gentian kenaf (KF) sebagai pengisi dan polipropilena (PP) sebagai pengikat. Ujian tegangan dilakukan untuk menentukan ketegangan spesimen. Hasilnya menunjukkan spesimen yang dirawat mempunyai tegangan yang tinggi pada 5 wt.% natrium hidroksida (NaOH) berbanding 10 wt.% berat dan 20 wt.% berat. Tekanan tegangan optimum adalah 40 wt.% berat KF (5 wt.% NaOH, 5 wt.% MAPP) dengan nilai 21.38 MPa. Ujian lenturan dilakukan pada KF yang tidak dirawat dan dirawat yang PP tulen, 10 wt.% KF, dan 20 wt.% KF mengikut berat kepada PP. Hasil daripada tegasan lenturan menunjukkan spesimen yang dirawat menunjukkan keseimbangan yang lebih baik pada 20 wt.% PP / KF (5 wt.% NaOH) dengan 30.25 MPa. Sementara itu, 40 wt.% KF (5 wt.% MAPP) memberikan kitaran hayat kelesuan yang tinggi pada semua tahap tekanan 90 %, 80 %, 70 %, 60 % dan 50 % kerana struktur spesimen kurang hancur disebabkan oleh ujian kelesuan. SEM digunakan untuk mematuhi ciri-ciri morfologi PP / KF. Ikatan permukaan yang baik antara KF dan PP adalah 5 wt.% NaOH disebabkan kurang kekotoran dan kandungan lignin. Keseluruhan 5 wt.% NaOH dengan 40 wt.% PP / KF (5 wt.% MAPP) menunjukkan hasil yang terbaik dan ia layak untuk menggantikan produk gentian kenaf polimer campuran semasa.

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LIST OF SYMBOLS AND ABBREVIATIONS

σ	-	Stress
σ_a	-	Stress amplitude
σ_{max}	-	Stress maximum
σ_{min}	-	Stress minimum
σ_m	-	Mean stress
%	-	Percentage
Ω	-	Ohm
+	-	Plus
-	-	Minus
×	-	Multiply
α	-	Alpha
AA	-	Acrylic acid
ASTM	-	American Society for Testing Machine
A	-	Area
AC	-	Alternative current
β	-	Beta
b	-	Material constant
BTU	-	British Thermal Unit
C	-	Carbon
°C	-	Celsius
CO_2	-	Carbon dioxide
CH	-	Carbon-hydrogen
CH_2OH	-	Hydroxymethyl

CH_3O	-	Trimethyl Phosphite |
cm^2	-	Square centi-meter
D	-	Diameter
d	-	Depth
DC	-	Direct current
E	-	Young modulus
EP	-	Epoxy
exp	-	Exponential
f	-	Frequency
F	-	Force
F_{max}	-	Maximum load
FKMP	-	Faculty of Mechanical and Manufacturing Engineering
FRIM	-	Forest research Institute Malaysia
FRP	-	Fibre Reinforced Composites
γ	-	Gamma
g	-	Gram
g/cm^2	-	Gram per square centimetre
GPa	-	Giga-pascal
H	-	Hydrogen
HCF	-	High Cycles Fatigue
HO	-	Hydroxide
Hz	-	Hertz
k	-	Constant
KF	-	Kenaf Fibre
kg	-	Kilogram
kg/ha	-	Kilogram per hectare
KKTM	-	Kolej Kemahiran Tinggi MARA
kN	-	Kilonewtons
L	-	Length
ꞁo	-	Original length
ΔL	-	Extension length
LCA	-	Life Cycle Analysis
LCF	-	Low Cycles Fatigue

LEFM	-	Linear Elastic Fracture Mechanics
LKTN	-	Board of Kenaf and Tobacco State
ISO	-	International Standard Organization
In	-	Natural logarithm
m	-	mass
MAH	-	Maleic Anhydride
MAPP	-	Maleic Anhydride Grafted Polypropylene
min	-	Minute
mg	-	Milli-gram
mm	-	Milli-meter
mm/min	-	Milli-meter per minute
µm	-	Micron-meter
MPa	-	Mega-pascal
N_f	-	Number of cycles
NaOH	-	Sodium hydroxide
N	-	Newton
O	-	Oxygen
OCH_3	-	M-dicyanobenzene
OVAT	-	One Variable At a Time
PALF	-	Pineapple Leaves Fibre
PEM	-	Polymer Electrode Membrane
PE	-	Polyethylene
PH	-	Potential of hydrogen
PS	-	Polystyrene
PP	-	Polypropylene
PP / KF	-	Kenaf Fibre Reinforced Polypropylene Composite
PUR	-	Polyurethanes
PVC	-	Polyvinyl chloride
PCL	-	Polycaprolactone
PPgma	-	Anhydride Modified Polypropylene
PMMA	-	Polymethyl Methacrylate
PMC	-	Polymer Matrix Composites
PCL	-	Polycaprolactone

PMMA	-	Polymethyl Methacrylene
PS	-	Polystyrene
psi	-	Per square inch
PVR	-	Polyurethanes
r	-	Radius
R	-	Stress ratio
$R\epsilon$	-	Fully reverse deformation
s	-	Century
SEM	-	Scanning Electron Microscopy
Sdn. Bhd.	-	Sendirian Berhad
S_{max}	-	Stress level
SIRIM	-	Industrial Research Institute Malaysia
S-N	-	Stress life
t	-	Thickness
UP	-	Polystyrene
UTM	-	Universal Testing Machine
UTHM	-	University Tun Hussein Onn Malaysia
σ_{UTS}	-	Ultimate Tensile Strength
V	-	Volt
v	-	Volume
W	-	Width
WPC	-	Wood Polymer Composites
wt.%	-	Weightage
w/w	-	Weight by weight
xs	-	Magnifications

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CHAPTER 1

INTRODUCTION

1.1 Research background

Historically, environmental awareness has led to an increase of interest in developing sustainable material in exchange to the material made from fossil based resources. Reinforcing fibres and polymers from renewable resources like natural fibre is one of the solutions to create furniture that is environmental friendly and have renewable composite materials for applications such as wardrobe and chair. For example, natural fibre is usually used as wood plastic composites (non-structure) like decking, chair and ceiling. Based on their mechanical properties, natural fibre is suitable for reinforcement in composite material. However, there are many challenges that need to be overcome for profitable commercial applications (Almgren, 2010).

Over the years, environmental friendly natural fibre has been widely used in polymer composites manufacturing to obtain desirable thermal mechanical and functional properties of the product (Subasinghe *et al*., 2015). Generally, there are three classifications of fibres which are natural fibre, regenerated fibre and synthetic fibre. These fibres are often used in the manufacture of other materials. Each type of fibres has their own use with natural fibre which is commonly used in industry. Natural fibre can be further classified into three categories which are vegetable, animal and mineral. Today an environmental friendly composite is needed to replace the conventional composites. With that, the use of natural fibre as reinforcing for polymer matrix has advanced remarkably and received worldwide attention (Suriania *et al.*, 2015).

The use of natural fibres such as pineapple leaf, bamboo, jute, sugar cane, coir fibre, flax, hemp and sisal as filler to be reinforced polymer matrix plastics has highly developed and caught many researchers' attention. Natural fibre based composite has attracted scientists and manufacturers owing to current use of natural fibre polymer composite materials in terms of applications in the production of automotive trim, window frames, roof shingles, and residential decking. According to Suriania *et al*., (2015) state that, due to an increasing demand in the prospective of natural fibres composites or wood polymer composites especially in main structural such as building and motor vehicles, fundamental studies of their mechanical behaviour are essential to allow their application. Besides, natural fibre plastic composites were included in the group of natural fibre polymer composites and known as filled thermoplastics consisting primarily of natural fibres and thermoplastic polymer such as polyethylene (PE), polyvinyl chloride (PVC) or polypropylene (PP) (Ngo *et al*., 2008).

Plastic which can be produced under the temperature of 200 °C are commonly used. Any reused plastic that can dissolve and process below degradation point of 200 ºC is proper for manufacturing natural fibre polymer composite materials. The selection of plastic depends on the specific use desired (High *et al*., 2008). Natural fibre polymer composites are thermoplastic polymers that fill with fibres flour at many concentrations and have attracted both research and commercial interest because of its environmental friendly factor (Mazzanti and Mollica, 2015). The global analyses about growth market natural fibre polymer composites material had been conducted by Netherlands agency as an opportunity for new developments. From the analyses, it can be concluded that an expansion of natural fibre based polymer production capacity from 3.5 million tons today up to 12 million tons in 2020 will overtake the place according to plans of producers. It means that, there is an increase in shares of the sum construction polymer composite production world-wide from 1.5 % to 3 %. The results showed that natural fibre polymer composites are placed on the market at higher prices than most conventional polymers (Dammer and Scholz, 2013).

Asia has turned to be a key region for natural fibre composite based on polymers and their originators. The drop of natural fibre polymer composite in market is raising fast in Asia. The increasing of market perception of natural fibre polymer composite leads to their volumes rising strongly and that was today. Europe has reached an advanced natural fibre plastic composites market stage as presented in Figure 1.1. Polypropylene (PP) is used to lead in European production, but this has converted, as shown in Figure 1.2. Meanwhile PVC and PE are regularly used in European decking production. Natural fibres are relatively inexpensive and the cost of natural fibres lies in the lower region. The increase of demand based on natural fibre like wood decking and thermal has improved wood headed to a slight decrease of the expense (Dammer and Scholz, 2013).

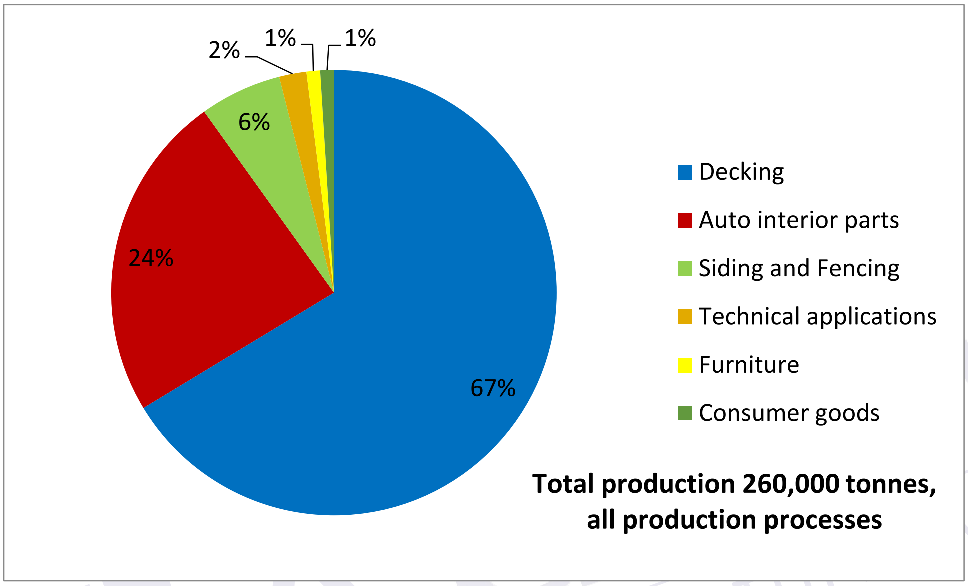

Figure 1.1: Application sector of natural fibre polymer composite in Europe 2012 (Dammer and Scholz, 2013)

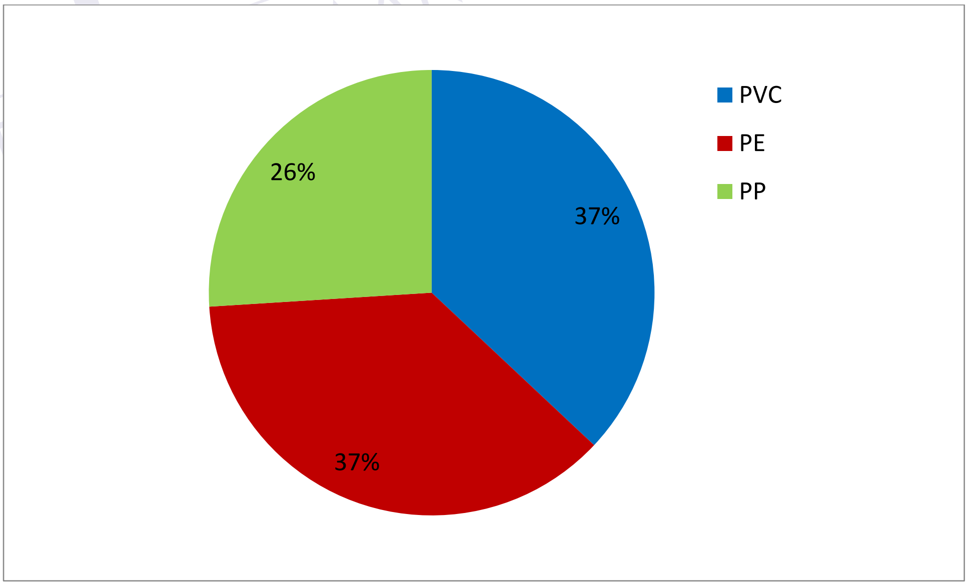

Figure 1.2: Polymer type used by European for natural fibre polymer composite in decking application extrusion (Dammer and Scholz, 2013)

Polymer fibre composites are mostly applied as materials production in industry. The ultimate goal of reinforcement is to increase the strength at the highest value potential (Faludi *et al*., 2014). Natural fillers are hydrophilic and thermoplastics are hydrophobic. Hydrophilic and hydrophobic materials are defined by the geometry of water on a flat surface. Apart from that, natural fillers are generally unsuited with thermoplastics but it can be developed by providing some surface modifications and treatment on the natural fillers such as modification with alkali treatment, and acetylation that will effectively recover their compatibility by chemically increasing the interfacial bonds between natural cellulosic fibres and polymers matrix (Hong *et al*., 2014). Possibility of problem arising using thermoplastic composites in structural applications involves their fatigue consistency under various environment and loading conditions. Fatigue consistency is an area of research that is gaining more consideration for civil structures, especially in the scope of fibre reinforced composites (FRP). Wood plastic composite system conducted by industry like building materials, need to consider their life span which is vital parameter to recognize the material as a worthwhile solution (Slaughter, 2004). Meanwhile, the moisture absorption causes opposing result on the mechanical and physical properties of natural fibre polymer composite with such effect include stiffness and strength reductions, matrix cracking, potential mass load and dimensional instability (Srubar *et al*., 2014).

In this research, the raw materials from industry were supplied by ZFH Industries Sdn. Bhd. that produce natural fibre polymer composite based on kenaf fibre and polypropylene polymer matrix with the addition of coupling agent. This natural fibre polymer composites were investigated through alkali treatment concentration with the implement tensile test, flexural test and fatigue test. Instead of that, the variation percentage of chemical content which is sodium hydroxide was applied and analysed to classify the characterization properties of kenaf fibre that will affect the mechanical properties especially. The natural fibre polymer composite is fabricated by following the International Standard Organization (ISO) 527 and 178 and American Society for Testing and Material (ASTM) D3039 and D3479. After this study is completed, the data obtained will be provided to ZFH industries as their reference and evidence to support their industrial project furniture. Throughout this research, it will decide whether this product is applicable to be implement in terms of quality improvement of product itself as well as an alternative for natural fibre in composite materials opening up for further industrial possibilities. It is important to change or

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